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Improved water capture and erosion reduction through furrow diking☆

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ABSTRACT

Crop production in Georgia and the Southeastern U.S. can be limited by water; thus, supplemental irrigation is often needed to sustain profitable crop production. Increased water capture would efficiently improve water use and reduce irrigation amounts and other input costs, thus improving producer's profit margin. We quantified water capturing and erosional characteristics of furrow diking by comparing runoff (*R*) and soil loss (*E*) from furrow diked (DT) and non-furrow diked tilled (CT) systems. A field study (Faceville loamy sand, Typic Kandiudult) was established (2006 and 2007) near Dawson, GA with DT and CT systems managed to irrigated cotton (*Gossypium hirsutum* L.). Treatments included: DT vs. CT; DT with and without shank (+/− S); and rainfall simulation performed (0, 60 days after tillage, DAT). Simulated rainfall (50 mm h^{-1} for 1 h) was applied to all 2 m × 3 m plots ($n = 3$). All runoff and *E* were measured from each flat, level sloping 6-m^2 plot (slope = 1%). Compared to CT, DT decreased *R* and *E* by 14–28% and 2.0–2.8 times, respectively. Compared to DT − S, DT + S decreased *R* and *E* by 17–56% and 26% to 2.1 times, respectively. Compared to sealed/crusted soil conditions at 60 DAT, simulating rainfall on a freshly tilled seedbed condition (DAT = 0) decreased *R* by 69% to 3.4 times and increased *E* by 27%. DT0 + S + RF0 plots (best-case scenario) had 2.8 times less *R*, and 2.6 times less *E* than CT − S + RF60 plots (worst-case). Based on $1.17 ha-$mm^{-1}$ to pump irrigation water and $18.50 ha^{-1} for DT, a producer in the Coastal Plain region of Georgia would recover cost of DT by saving the first 16 ha-mm of water. The DT + S system is a cost-effective management practice for producers in Georgia and the Southeastern U.S. that positively impacts natural resource conservation, producer profit margins, and environmental quality.

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1. Introduction

Most of Georgia and the Southeastern U.S. receive ∼1250 mm of rainfall annually. This rainfall tends to be bi-modal in nature and characteristically has short duration–high intensity, runoff producing storms with extended periods of drought during the crop growing season. As a result, supplemental irrigation is often needed to prevent yield-limiting water stress.

Highly weathered, Coastal Plain soils of Georgia and the Southeast have been intensively cropped under conventional tillage (CT) systems, have relatively sandy surfaces, tend to be drought-prone, and are susceptible to compaction, runoff, and erosion. Crop production in this region can be limited by water. Management practices are needed to increase water (rainfall, irrigation) capture and infiltration resulting in improved water use and reduced irrigation costs, thus sustaining natural resources and profitable crop production. Furrow diking creates a series of surface depressional storage basins or micro-catchments between crop rows with small earthen dams over short intervals to more effectively catch and retain rainfall and/or irrigation, thus promoting infiltration and preventing runoff and erosion.

Agricultural demand for water in Georgia and the Southeast, along with rising fuel costs, continue to place importance on water conservation. However, sustainable crop production demands more efficient water use as the amount of irrigated land has increased steadily (∼610,000 ha in 2004, Harrison, 2005), while farm diesel costs increased 3+ times from 2002 to 2008. Water conservation in agricultural settings is essential, including accurate quantification of how well management practices conserve water.

In Georgia and the Southeast, a major effort has been undertaken to conserve soil resources and reduce water and energy requirements for row crop production, mainly through conservation tillage. Conservation tillage adoption in the region has steadily increased; yet, a significant portion of the land

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continues to be managed to CT. On-farm management practices are needed by producers that continue to use CT or that have recently converted to conservation-till to take better advantage of water (rainfall, irrigation) available to them.

Furrow diking (DT), or some form thereof (tied ridge, basin tillage, furrow damning, basin listing, micro-basin tillage), is commonly used in arid and semi-arid regions throughout the World (Gerard et al., 1983, 1984; Jones and Clark, 1987; Krishna, 1989; Hulugalle, 1990; Kincaid et al., 1990; Jones and Stewart, 1990; Carter and Miller, 1991; McFarland et al., 1991; Hackwell et al., 1991; Baumhardt et al., 1993; Twomlow and Bruneau, 2000; Wiyo et al., 2000; Howell et al., 2002; Jensen et al., 2003; Jones and Baumhardt, 2003; Brhane et al., 2006; Brhane-Tesfahunegn and Wortmann, 2008). DT has been used since the 1930s in the Great Plains region of the U.S. (Jones and Stewart, 1990). In the 1950s, DT in this region was abandoned due to equipment limitations, weed pressure, mixed crop yield responses, and conservation tillage adoption. In the 1970s, DT was again utilized as a soil and water conservation practice, with improved equipment and herbicides for weed control, in summer crop production when runoff potential is high.

DT systems increase surface depressional storage, rainfall/irrigation capture, infiltration, and decrease runoff and soil loss (Asrstad and Miller, 1973; Gerard et al., 1983, 1984; Rawitz et al., 1983; Jones and Clark, 1987; Jones and Baumhardt, 2003). However, little information has been reported on DT applications in the Southeastern U.S. (Hackwell et al., 1991; Bader et al., 1994; Bader and Wilson, 1996). In Alabama, Hackwell et al. (1991) reported that DT increased depth of water intake and reduced irrigation-induced runoff and erosion from a sandy loam Ultisol exposed to low energy precision application sprinkler irrigation.

Current agricultural water issues and the need to reduce input costs in farming operations add importance to making sound irrigation and management decisions to ensure efficient water use, natural resource conservation, and on-farm profitability. Even though DT has been utilized in many parts of the World for different crops, the success of DT will depend on rainfall characteristics, intrinsic soil properties, and cropping/tillage systems used in any given region. Thus, producers of other crops in other regions of the World may benefit from DT technology. We hypothesize that DT systems in Georgia and the Southeastern U.S. can improve economic returns by improving water capture (more infiltration, less runoff), crop yield/quality, and reducing supplemental irrigation inputs and fossil fuels/energy consumption. Ultimately, DT systems should allow for more efficient use of rainfall and supplemental applied irrigation subsequently improving overall yield potential and profit margins, giving producers in Georgia and the Southeastern U.S. a management tool that takes better advantage of natural rainfall and/or irrigation and extend the time between supplemental irrigations. The objective of this study was to quantify water capturing and erosional characteristics of DT by comparing runoff and sediment delivery from furrow diked (DT) and non-furrow diked tilled (CT) systems. Agronomic data collected in association with this study are described in a companion paper (Nuti et al., 2009)

2. Materials and methods

2.1. Experimental site

The research site was located near Dawson, GA (N 31°46′, W 84°31′). The soil studied was a Faceville loamy sand (fine, kaolinitic, thermic Typic Kandiudult; 71% sand, 16% clay; slope = 1%), which occupies over 87,000 farmable ha in the Coastal Plain region of Georgia. Prior to this study, the site had been conventional tilled in a cotton–corn–peanut rotation since 2002. After each crop was harvested in the fall, stubble was disked twice and a rye or wheat cover crop planted. In the following spring, the cover crop was disked twice, field cultivated, and bedded. For each peanut crop, the soil was turned in the spring after disking the cover crop twice and limed before disking. This 2-year study (2006, 2007) was conducted in plot areas cropped to cotton (row spacing 0.9 m). DT was conducted immediately after tillage and planting cotton in the spring (days after tillage = 0), and created surface depressional storage basins between non-traffic crop rows that were 1.5 m long, 30 cm wide, and 20 cm deep (Fig. 1). DT is more effective when the soil is loose, thus may be done at planting (seedbed condition) in CT or behind cultivation. While cultivating, a ripper shank was used to reduce compaction and improve infiltration. The shank used was made of 1.6 cm by 10.5 cm steel and measures 45 cm from the tip to a point parallel to the back of the shank. It has replaceable wear points, and was operated at a depth of 18 cm.

2.2. Treatments

Treatments consisted of conventional (CT) and furrow diked (DT) tillage (Fig. 1), with or without a shank (+/− S), and simulated rainfall (RF) at 0 and 60 days after tillage (DAT). In May, 2006, two treatments were established and evaluated. First, conventional (freshly) tilled seedbed without a shank with rainfall simulated at 0 DAT (CT − S + RF0). Second, conventional tilled (non-furrow diked, crusted) seedbed without a shank with rainfall simulated at 60 DAT (CT − S + RF60). In May, 2007, five treatments were established and evaluated. First, conventional (freshly) tilled seedbed without a shank with rainfall simulated at 0 DAT

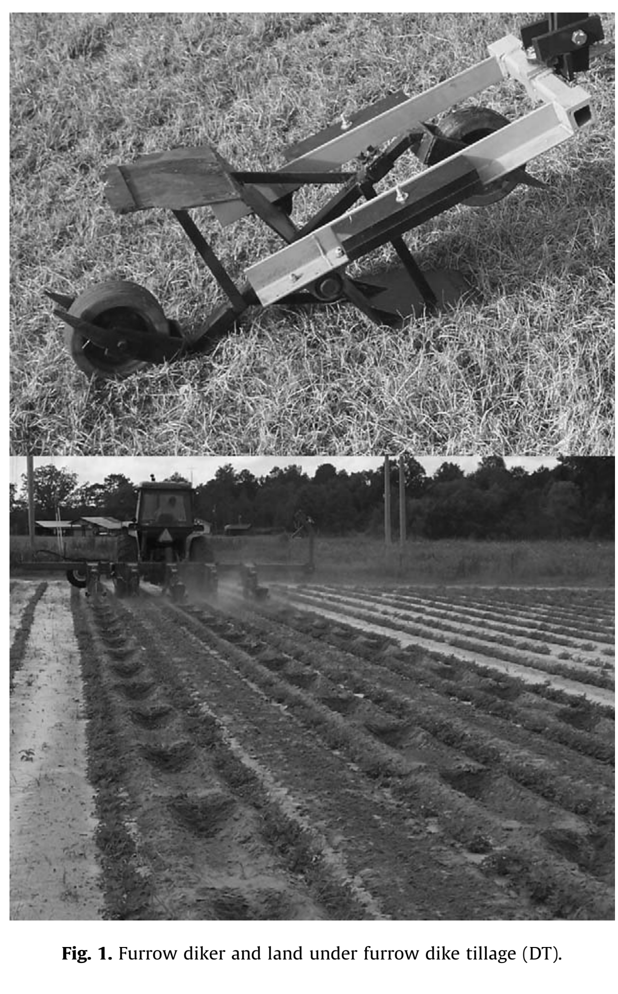

Fig. 1. Furrow diker and land under furrow dike tillage (DT).

(CT − S + RF0). DT treatments consisted of furrow diked (freshly) tilled just after planting without a shank with rainfall simulated at 0 DAT (DT − S + RF0); furrow dike tilled just after planting without a shank with rainfall simulated at 60 DAT (crusted) (DT − S + RF60); furrow diked (freshly) tilled just after planting with a shank with rainfall simulated at 0 DAT (DT + S + RF0); and furrow dike tilled just after planting with a shank with rainfall simulated at 60 DAT (crusted) (DT + S + RF60). DT was done on an every-other-row pattern. Note that the CT − S + RF0 (control, n = 6) treatment was evaluated in 2006 and 2007; and planting date for cotton was around the first of May of each year. All treatments evaluated for this study are listed in Table 1.

Table 1
Description of each of the treatments studied.

Tillage	Dike[a]	Operation conducted shank[a]	Rain[a]	Treatment notation
Seedbed (CT)	No	No	0	CT − S + RF0
Seedbed (CT)	No	No	60	CT − S + RF60
Diked (DT)	0	No	0	DT − S + RF0
Diked (DT)	0	No	60	DT − S + RF60
Diked (DT)	0	0	0	DT + S + RF0

DAT = days after tillage; CT = Conventional tillage; DT = Diked tillage; S = Shank; RF = Rainfall.
[a] DAT.

2.3. Rainfall simulations

Rainfall simulation plots (2-m wide, 3-m long) were established on each treatment (n = 3) in May of 2006 and 2007, resulting in 21 rainfall simulation plots evaluated. For plots receiving simulated rainfall at 60 DAT, cotton plants were clipped at ground level and removed just prior to simulating rainfall to make direct comparisons to treatments obtained at 0 DAT. An area surrounding each 6-m^2 simulator plot was treated like the test area to allow soil material to be splashed in all directions. Soil water content was determined gravimetrically (Gardner, 1986) from samples taken from three areas around each 6-m^2 plot just prior to each simulated rainfall event (0–1 and 1–15 cm depths). Each 6-m^2 plot, oriented lengthwise with the row, had either a furrow diked row (centered) with two half beds (one row of cotton per half bed) on either side of the furrow diked middle or a wheel track (centered) with two half beds on either side of the wheel track middle (CT non-diked plots). Simulated rainfall was applied to each 6-m^2 plot at a target intensity (I) of 50 mm h^{-1} for 60 min (ave. I for the 21 runs/plots = 50.7 mm h^{-1}; cv = 5%). Thirty-five year average annual rainfall volume was 1250 mm; 35-year average monthly rainfall volume (May) was 83.8 mm; and 35-year average maximum rainfall I for Spring (March, April, May) was 163 mm h^{-1}. The 35-year average I of the most frequently occurring Spring-time storm was 57 mm h^{-1}. Rainfall was applied with an oscillating nozzle rainfall simulator (Frauenfeld and Truman, 2004) that used 80150 Veejet nozzles (median drop size = 2.3-mm). The simulator was placed 3 m above each 6-m^2 plot. Well water was used in all simulations, and had an average pH of 7.7 (cv = 0.6%) and EC of 0.002 S cm^{-1} (cv = 2%).

Runoff (R) and sediment yields (E) from each 6-m^2 plot were measured continuously at 5-min intervals during each simulated rainfall event. Runoff and E were collected in 1-L Nalgene (autoclaveable) bottles. Each bottle was weighed (bottle + water + sediment), dried at 105 °C for 24 h, then weighed again (bottle + sediment). Runoff and E were determined gravimetrically. Infiltration (INF) was calculated by difference (rainfall − run-runoff); the parameter d INF was calculated by difference ($INF_{max} - INF_{min}$). Water for crop use estimates were calculated from INF values for each treatment and an assumed ET value.

2.4. Data analysis

Means, coefficient of variations (cv, %), and standard error bars are given for measured data (n = 3). We performed unpaired t-tests (two-tailed distribution) to determine significance among treatment means using SigmaStat 3.1 (Systat, 2004.). All test statistics were evaluated at P = 0.05 unless otherwise noted. All other data analysis was conducted with Microsoft Office Excel 2003.

3. Results and discussion

Given our objective, we addressed the following questions. What was the effect of DT on runoff and sediment delivery from a Faceville loamy sand compared to CT? Given equipment and convenience considerations, is DT more effective and beneficial when a shank is used? What differences occur in runoff and soil loss from CT and DT systems when rainfall is simulated at 0 DAT on a freshly tilled seedbed condition compared to 60 DAT when soil surface is sealed/crusted due to natural rainfall and/or irrigation?

3.1. CT vs. DT

Overall, CT plots averaged 25% (20 mm h^{-1} vs. 16 mm h^{-1}) more runoff (R) than DT plots. For corresponding CT and DT treatments (CT − S + RF0, DT − S + RF0; CT − S + RF60, DT − S + RF60), CT plots averaged 14% (20 mm h^{-1} vs. 17.5 mm h^{-1}) more R than DT plots. Most R differences between CT and DT plots were associated with simulating rainfall at 60 DAT (RF60), not at 0 DAT (RF0) (Table 2). For CT − S + RF60 and DT − S + RF60 plots, CT plots had 28% more R than DT plots (P = 0.04). Similarly, Rawitz et al. (1983) reported that DT plots had only 10% of the runoff of non-diked ridged plots, and concluded that DT was an effective practice to enhance infiltration and conserve water. Others have reported similar runoff reductions and water conservation trends with DT in semi-arid regions of Texas (Gerard et al., 1983, 1984; Jones and Clark, 1987).

Table 2
Hydrology and erosion parameters for each treatment studied.

Treatment	AWC[a] (0–1 cm) (%)	AWC (1–15 cm) (%)	Int. (mm h^{-1})	INF (mm h^{-1})	INF (mm h^{-1})	R (mm h^{-1})	R (%)	R_{max} (mm h^{-1})	E (g)	E_{max} (kg m^{-2} h^{-1})
CT − S + RF0	2.6	8.2	52 (05)[b]	39 (04)	72 (01)	15 (07)	28 (09)	29 (04)	1563 (10)	0.67 (07)
CT − S + RF60	3.4	6.8	48 (09)	23 (15)	47 (10)	25 (09)	53 (11)	35 (09)	1454 (04)	0.46 (08)
DT − S + RF0	0.7	6.8	52 (03)	38 (06)	74 (04)	14 (11)	26 (12)	26 (03)	581 (05)	0.18 (05)
DT − S + RF60	1.4	4.9	50 (03)	29 (08)	59 (05)	21 (06)	41 (08)	30 (05)	738 (03)	0.22 (10)
DT + S + RF0	1.3	8.9	51 (05)	42 (09)	83 (05)	9 (16)	17 (21)	19 (08)	552 (14)	0.17 (17)
DT + S + RF60	1.1	5.0	51 (04)	34 (02)	66 (03)	18 (08)	34 (05)	24 (16)	491 (22)	0.15 (16)

[a] AWC = antecedent water content (%); Int. = rainfall intensity (mm h^{-1}); INF = infiltration (%, value is % of simulated rainfall); R = runoff (%, value is % of simulated rainfall); R_{max} = maximum 5 min runoff rate (mm h^{-1}); E = soil loss (g); E_{max} = maximum 5 min soil loss rate (kg m^{-2} h^{-1}).
[b] x (cv).

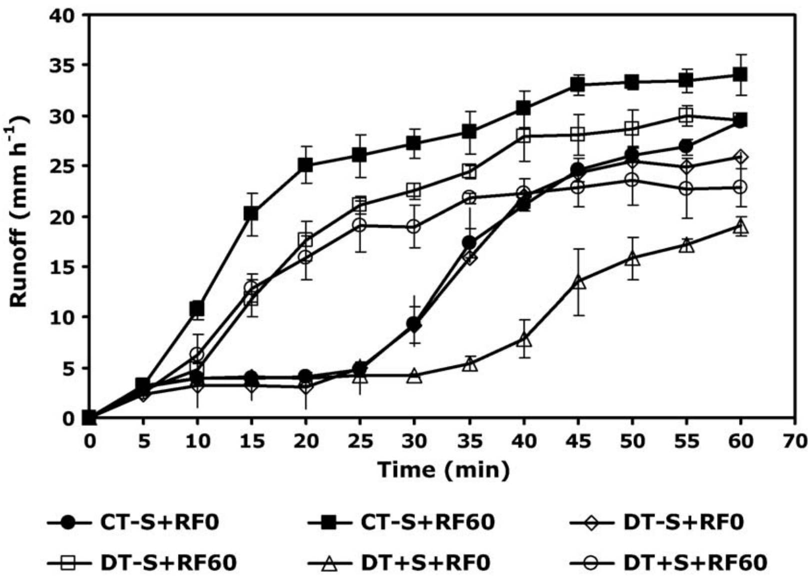

Fig. 2. Runoff rates from each treatment during the 1 h of simulated rainfall (I = 50 mm h^{-1}; bars = standard error, S.E.).

Runoff rates increased with time (Fig. 2). For DT and CT plots at 0 DAT (CT − S + RF0, DT − S + RF0), R rates remained relatively constant for the first 25–30 min of the simulation. From 30 to 60 min, separation in R rate loss curves occurred, with DT plots having lower R rates than corresponding CT plots. At 60 DAT (CT − S + RF60, DT − S + RF60), steady-state R rates for CT plots were on average 21% greater than those for DT plots. Also, CT plots averaged 28% higher (32 mm h^{-1} vs. 25 mm h^{-1}) maximum runoff rates (R_{max}) during the 60 min rainfall duration than DT plots (Table 2). At 0 DAT (CT − S + RF0, DT − S + RF0), CT plots had 12% higher R_{max} values than DT plots (P = 0.004). At 60 DAT (RF60), CT plots had numerically (17%) higher R_{max} values than DT plots (NS, P = 0.08).

Overall, CT plots averaged 2.6 times (1508 g vs. 591 g) more soil loss (E) than DT plots. At 0 DAT (CT − S + RF0, DT − S + RF0), CT plots had 2.8 times more E than DT plots (P = 0.0005) (Table 2); when simulating rainfall at 60 DAT (CT − S + RF60, DT − S + RF60 plots), CT plots had 2 times more E than DT plots (P = 0.0001). Similarly, Rawitz et al. (1983) reported that DT plots decreased soil loss 10- and 25-fold compared to non-diked plowed/disked plots and ridged plots, respectively.

Soil loss rates increased with time (Fig. 3), with CT plots having overall greater E rates than DT plots. For corresponding DT and CT plots at 0 DAT (CT − S + RF0, DT − S + RF0), E rates were similar and gradually increased for the first 25 min of the simulation. From 25 to 60 min, separation in E rate curves occurred, with CT plots having higher E rates than corresponding DT plots. Steady-state E rates for CT plots were 3.6 times greater than those for DT plots. At 60 DAT (CT − S + RF60, DT − S + RF60), E rates were similar for only the first 10 min of the simulation. From 10 to 60 min, separation in E rate curves occurred, with CT plots having higher E rates than corresponding DT plots. Also, CT plots averaged 3.2 times (0.57 kg m^{-2} h^{-1} vs. 0.18 kg m^{-2} h^{-1}) higher maximum soil loss rates (E_{max}) during the 60 min rainfall duration than DT plots (Table 2). At 0 DAT (RF0), CT plots had 3.7 times higher E_{max} values than DT plots (P = 0.0001). At 60 DAT

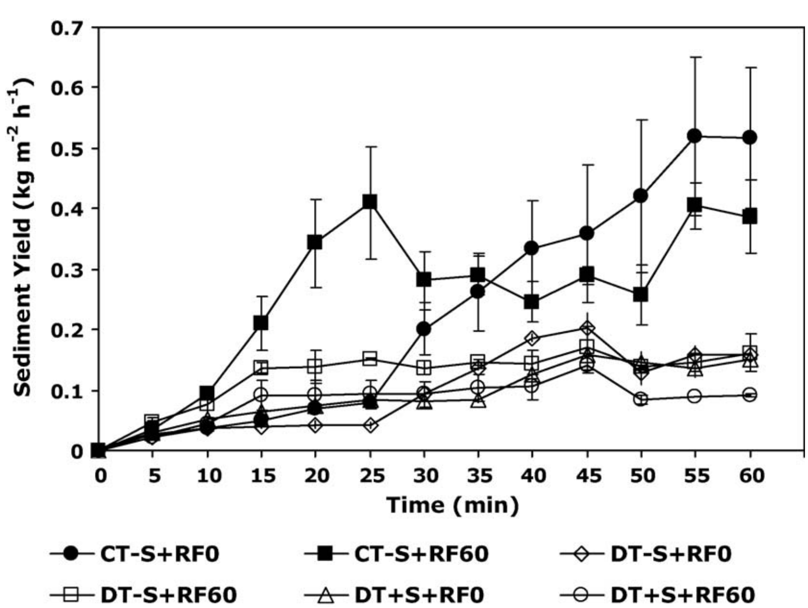

Fig. 3. Sediment yield rates from each treatment during the 1 h of simulated rainfall (I = 50 mm h^{-1}; bars = standard error, S.E.).

(RF60), CT plots had 2.7 times higher E_{max} values than DT plots ($P = 0.0006$).

3.2. DT +/− shank

DT can be done with or without a shank. Given equipment and convenience considerations associated with using a shank, we were interested in knowing if DT is more effective when a shank is used. Overall, plots where a shank was not used averaged 39% (18.8 mm h^{-1} vs. 13.5 mm h^{-1}) more *R* than plots where a shank was used. For corresponding plots with and without a shank (DT − S + RF0, DT + S + RF0; DT − S + RF60, DT + S + RF60), DT − S plots averaged 30% (17.5 mm h^{-1} vs. 13.5 mm h^{-1}) more *R* than DT + S plots. At 0 DAT (DT − S + RF0, DT + S + RF0), DT − S plots had 56% more *R* than DT + S plots ($P = 0.01$). When simulating rainfall at 60 DAT (DT − S + RF60, DT + S + RF60), DT − S plots had 17% more *R* than DT + S plots ($P = 0.05$). Also, DT − S plots averaged 30% (28 mm h^{-1} vs. 21.5 mm h^{-1}) higher maximum runoff rates (R_{max}) during the 60 min rainfall duration than DT + S plots. At 0 DAT (RF0), DT − S plots had 37% higher R_{max} values than DT + S plots ($P = 0.001$). At 60 DAT (RF60), DT − S plots had 25% higher R_{max} values than DT + S plots ($P = 0.0006$).

For corresponding DT − S and DT + S plots at 0 DAT (DT − S + RF0, DT + S + RF0), *R* rates remained relatively constant for the first 25–30 min of the simulation (Fig. 2). From 30 to 60 min, separation in *R* rate loss curves occurred, with DT + S plots having lower *R* rates than corresponding DT − S plots. At 60 DAT (RF60), relative differences in *R* rates increased for the 15–60 min duration. Steady-state *R* rates for DT − S plots were on average 39% greater than those for DT + S plots.

Overall, DT − S plots averaged 2.1 times (1084 g vs. 522 g) more *E* than DT + S plots. For corresponding DT + S and DT − S treatments, DT − S plots averaged 26% (660 g vs. 522 g) more *E* than DT + S plots (Table 2). At 0 DAT (RF0), no significant differences in *E* or E_{max} values were found between DT + S and DT − S plots. When simulating rainfall at 60 DAT (DT − S + RF60, DT + S + RF60), DT − S plots had 50% more *E* than DT + S plots ($P = 0.01$). Also, DT − S plots averaged 25% higher (0.20 kg m^{-2} h^{-1} vs. 0.16 kg m^{-2} h^{-1}) E_{max} values during the 60 min rainfall duration than DT + S plots. At 60 DAT (RF60), DT − S plots had 47% higher E_{max} values than DT + S plots ($P = 0.01$).

For corresponding DT + S and DT − S treatments, *E* rates were similar for all DT treatments, never exceeding 0.20 kg m^{-2} h^{-1} throughout the entire 60 min duration (Fig. 3). Steady-state *E* rates for all DT treatments ranged from 0.8 to 0.15 kg m^{-2} h^{-1}.

3.3. CT and DT longevity (RF0-freshly tilled vs. RF60-sealed/crusted)

Simulating rainfall on a freshly tilled seedbed condition (DAT = 0) was expected to yield different *R* and *E* results from a crusted, sealed condition (DAT = 60). Overall, RF60 plots averaged 3.4 times (44 mm h^{-1} vs. 13 mm h^{-1}) more *R* than RF0 plots (Table 2). For corresponding plots (CT − S + RF0, CT − S + RF60; DT − S + RF0, DT − S + RF60; DT + S + RF0, DT + S + RF60), RF60 plots averaged 69% more *R* than RF0 plots. CT plots had the greatest INF differences between RF0 and RF60 plots, with RF0 plots having 69% more INF than RF60 plots ($P = 0.0003$). DT + S plots had the greatest *R* (2×, $P = 0.001$) differences between RF0 and RF60 plots. Also, RF60 plots averaged 21% higher R_{max} values than RF0 plots. CT and DT − S plots had 21 and 15% higher R_{max} values for RF60 plots compared to RF0 plots ($P = 0.02$ and $P = 0.01$). Runoff rates were higher for RF60 plots compared to RF0 plots (Fig. 2). Steady-state *R* rates for RF60 plots were on average 25% greater than those for RF0 plots.

The DT − S + RF60 plots had 27% more *E* than DT − S + RF0 plots ($P = 0.001$). Also, CT − S + RF0 plots had 46% higher E_{max} values than CT − S + RF60 plots ($P = 0.003$). For CT and DT + S plots; RF0 plots had 33 and 66% greater steady-state *E* rates than RF60 plots, respectively (Fig. 3).

3.4. Impact of furrow diking

The CT − S + RF60 plots (crusted) represented the worst-case scenario; DT + S + RF0 plots (freshly furrow diked) represented the best-case scenario, as DT + S + RF0 plots had 2.8 times less *R*, and 2.6 times less *E* than CT − S + RF60 plots (Table 2). The CT − S + RF60 plots received irrigation and/or natural rainfall over a 60-day period (rainfall and irrigation during the period totalled 226 mm in 2006 and 241 mm in 2007), resulting in the surface of the Faceville loamy sand at 60 DAT being significantly altered from its seedbed condition (0 DAT). This is evident by the fact that the freshly tilled, unsealed/uncrusted CT − S + RF0 plots had 69% more INF and 67% less *R* than the sealed/crusted CT − S + RF60 plots. Conversely, DT + S + RF0 plots were freshly tilled (unsealed) due to the DT operation, and were more efficient in capturing and retaining simulated rainfall due to increased surface depressional storage created by the formed furrow dike as compared to the CT treatment.

To further illustrate surface alteration effects on rainfall partitioning from CT and DT treatments, the change in infiltration (d INF) was calculated for each treatment (Table 3). Values of d INF ($INF_{max} - INF_{min}$) have been used as an indicator of surface sealing/crusting, resulting in alterations of the soil surface (Truman and Bradford, 1993; Truman et al., 2005). The greater the d INF value, the greater the change in the soil surface of a respective treatment. Range of d INF values was 16–35. The CT − S + RF60 plots had the greatest d INF value; DT + S + RF0 plots had the lowest d INF value, a difference of 2.2 times.

DT systems capture and retain more water and lose less water as runoff compared to CT systems, yet the question remains for producers as to whether DT management practices that generate less runoff and increased infiltration will translate into more water for crop use, less supplemental irrigation, and improved profit margins. To address this, we used data from this study and two assumptions to calculate estimated days of water for crop use and subsequent irrigation values. We assumed all INF was available to the crop and evapotranspiration (ET) was 6 mm d^{-1}. Then, 23 mm of water infiltrated CT − S + RF60 plots and 42 mm of water infiltrated DT + S + RF0 plots during the 1 h simulated rainfall duration, resulting in 3.8 days of water for crop use for CT − S + RF60 plots (worst-case) and 7 days of water for crop use for DT + S + RF0 plots (best-case) (Table 3). This difference (3.2 days of water for crop use or 84%) is important for low water holding capacity soils in the Coastal Plain during extended drought conditions that often occur during the growing season. Thus, based on these applied, calculated examples of worst-case and best-case

Table 3
Surface sealing and water for crop use parameters for each treatment studied.

Treatment	d INF[a]	Water for Crop use	
		25 mm (days)	50 mm (days)
CT − S + RF0	33 (05)[b]	3.9[c]	6.5
CT − S + RF60	35 (12)	1.5	3.8
DT − S + RF0	24 (03)	3.6	6.3
DT − S + RF60	31 (19)	2.3	4.8
DT + S + RF0	16 (12)	3.6	7.0
DT + S + RF60	22 (17)	2.5	5.7

[a] d INF = $INF_{max} - INF_{min}$; water for crop use estimates (days) for 25 and 50 mm rainfall amounts.
[b] x (cv).
[c] Assumed ET = 6 mm d^{-1}.

scenarios and using the 25 mm water for crop use estimates (Table 3), Coastal Plain producers utilizing DT systems could irrigate 2.4 times (3.6 vs. 1.5) less than those using CT systems. In 2006 and 2007, CT cotton under similar conditions described herein received 11 and 28 irrigations and 273 mm and 711 mm of irrigation (actual, measured values), respectively. The 2-year average was 20 irrigations and 492 mm of irrigation water applied to CT cotton. Under this same illustrative scenario, a corresponding 2-year average of 8 irrigations or 205 mm of irrigation water would have been applied to DT cotton.

To further illustrate estimated water and financial savings with DT, we assumed a field size of 49 ha, a 50 mm rainfall event, and cost to pump irrigation water is \$1.17 ha mm^{-1}. A 50 mm rain over a 49 ha field is 24,666,694 L of water. The CT − S + RF60 plots had 53% of the rainfall amount (50 mm) applied was lost as runoff; DT + S + RF0 plots had 17% of the rainfall amount applied lost to runoff (Table 2). Thus, the 49 ha field managed to CT would have 11,593,346 L INF and 13,073,348 L *R*; the same field managed to DT would have 20,473,356 L INF and 4,193,338 L *R*. The difference between INF and *R* (8,880,010 L) would cost the producer farming the CT managed field \$1037 to pump the amount of water lost to *R* (not saved as INF) back onto the 49 ha field. This equates to \$21.16 ha^{-1}. Cost of DT is \$18.50 ha^{-1}, therefore, the estimated cost to the producer who utilized DT on his 49 ha field is \$908, an estimated \$129 savings for one rainfall event. Thus, using the best and worst-case scenarios in this study as examples, DT is clearly cost effective [\$21.16 ha^{-1} (savings) − \$18.50 ha^{-1} (cost) = \$2.66 ha^{-1} (profit) from a DT system in a single 50-mm rainfall event] in areas with runoff producing rainfall events as in the Coastal Plain region of Georgia. Water and financial savings do not include the environmental benefits of the reduction in natural resource degradation, and any associated contaminants transported by runoff and/or sediment.

4. Summary and conclusions

In May, 2006 and 2007, we simulated rainfall to quantify rainfall partitioning and sediment delivery from a Faceville loamy sand managed under conventional-tilled (non-furrow diked) (CT) and furrow diked tillage (DT) treatments with and without a shank (+/− S) representing fresh seedbed condition (DAT = 0) and for a sealed/crusted surface soil condition (DAT = 60). Field plots (2-m wide, 3-m long) received simulated rainfall (50 mm h^{-1} for 60 min). Runoff and soil loss were measured continuously.

How did DT effect runoff and sediment delivery compared to CT? Compared to DT, CT increased *R* by 14–28%, R_{max} by 12–28%, *E* by 2.0–2.8 times, and E_{max} by 2.7–3.7 times. DT increased water capture and water for crop use estimates, and reduced runoff and soil loss.

Given energy/fuel, equipment, and convenience considerations, is DT more effective and beneficial when a shank is used? Compared to DT + S, DT − S increased *R* by 17–56%, R_{max} by 25–37%, *E* by 26–50% (max = 2.1 times), and E_{max} by 25–47%. DT + S increased the water capture and water for crop use estimates, and reduced runoff and soil loss.

What differences occur in runoff and soil loss from CT and DT systems on a freshly tilled seedbed (DAT = 0) *compared to* 60 *DAT with sealed/crusted conditions due to natural rainfall and/or irrigation*? Compared to sealed/crusted soil conditions at 60 DAT (RF60), simulating rainfall on a freshly tilled seedbed condition just after tillage (RF0) increased INF by 24–69% and water for crop use estimates by 23–71%. Compared to RF0, RF60 increased *R* by 69% to 3.4 times, R_{max} by 15–26%, *E* by 27%, and E_{max} by 46%. Soil surface conditions deteriorate with time after tillage during the crop growing season increasing the risk of runoff, thus illustrating the need for soil and water conservation measures during the growing season.

DT + S + RF0 plots (best-case scenario) had 84% more days of water for crop use based on a 50 mm rainfall, 2.4 times more days of water for crop use based on a 25 mm irrigation, 2.8 times less *R*, and 2.6 times less *E* than CT − S + RF60 plots (worst-case scenario). Cost of DT is \$18.50 ha^{-1}. Thus, in areas with runoff producing rainfall events as in the Coastal Plain region of Georgia, saving the first 16 ha-mm of water offsets the cost of the DT system. Other benefits include the reduction in natural resource degradation and any associated contaminant transport by runoff and/or sediment. The DT + S system is a cost-effective management practice for producers in the Coastal Plain region of Georgia that has a positive impact on natural resource conservation, producer profit margin, and environmental quality.

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